DINOSAURIAN PALAEOBIOLOGY: A NEW ZEALAND PERSPECTIVE

J. WIFFEN

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The first known dinosaur bone from New Zealand was identified from the Late Cretaceous marine sandstones at the Mangahouanga Stream site in 1980 (Molnar, 1981). Since then isolated bones indicate that a variety of herbivores and carnivores were present after the separation from Gondwana 80-85 million years ago until their extinction. Though geographically polar in origin, survival for a long period on an island landmass suggests a temperate climate prevailed as New Zealand drifted north. ☐ *New Zealand, Cretaceous, dinosaur, palaeoclimate, palaeobotany, taphonomy.*

J. Wiffen, 138 Beach Road, Haumoana, Hawke's Bay, New Zealand, 5 July 1996.

The only dinosaur fossils so far found in New Zealand come from the Late Cretaceous Maastrichtian-Campanian marine sediments in the Mangahouanga Stream fossil site, North Island, New Zealand. These bones represent a diverse dinosaur fauna and the only record of terrestrial life from Mesozoic New Zealand. They include vertebrae and phalanges from 2-3 species of theropod, vertebrae (Fig. 1A) and a rib from an ankylosaur, an ilium (Fig. 1B) from an ornithopod and a rib fragment (Fig. 1C) from a sauropod (Molnar, 1981; Wiffen & Molnar, 1989; Molnar & Wiffen, 1994).

The bones are found in hard calcareous concretions, locally derived from the upper layers of the Maungataniwha Sandstone. This was laid down on the eastern coastline of ancient New Zealand in Campanian-Maastrichtian (Haumurian-Piripauan) times and is now exposed at the Mangahouanga Stream (Fig. 2). Isolated bones were carried from the adjacent landmass by rivers probably in seasonal floods — the larger bones dropped as the flow slowed through lagoonal or estuarine areas — prior to burial in riverborne debris in nearshore wave base deposits (Crampton & Moore, 1990; Moore & Joass, 1991; Wilson & Moore, 1988). They occur along with fossils of marine origin.

The described terrestrial bones are easily recognised (Fig. 3) and well preserved, with diagnostic features. So it seems likely that the bones weren't transported far from land to the site. When extracted from the rock, there is little apparent abrasive damage on the bone surface that occurred prior to burial. Most of the damage seen is recent, from exposure after the concretions have eroded out of the enclosing rock and split due to temperature extremes (i.e., winter frosts and hot dry summers), with resulting surfaces worn by running water.

SIGNIFICANCE

By and large the record of terrestrial life from ancient New Zealand isn't as good as those from elsewhere. Acid conditions produced by the high rainfall and extensive forest cover are thought to account for the generally poor fossil record (Fleming, 1962).

Consequently although the number of dinosaur bones identified to date is small, they are significant for several reasons:

1) They show that dinosaurs inhabited this part of Gondwana prior to its separation from the Marie Byrd Land area of western Antarctica (Stevens, 1985).

2) They are the first evidence that terrestrial vertebrates survived in New Zealand after its separation from Gondwana, as opposed to having arrived there by dispersal.

3) This is the only known Southern Hemisphere region where dinosaurs lived on a small island, for up to 15-20 million years, until their extinction.

What evolutionary changes, if any, occurred in these forms in the presumably static island environment, in the absence of migrations to New Zealand and with (presumably) decreased competition, are not known. To date no unique features have been seen to suggest morphological changes or geographic or climatic adaptations: however, considerably more complete fossil material is required to determine this.

Although similar taxa have been found from this period in Antarctica (Hooker et al., 1991; Hammer & Hickerson, 1994) no closely-related forms have been detected, in spite of the variety of taxa — ornithopod, sauropod and ankylosaur,

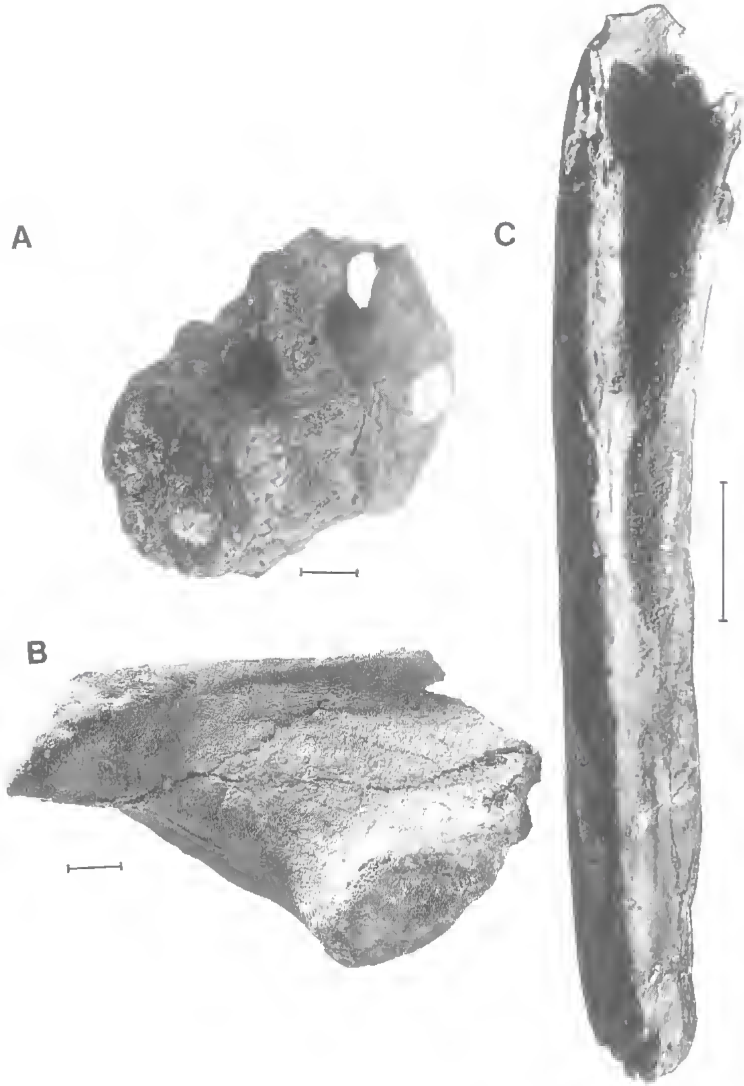

FIG. 1. A, Articulated nodosaurian caudal vertebrae (CD 546) from the Maungataniwha Sandstone, Mangahouanga Stream, in posterolateral oblique view. The specimen unfortunately exceeded the depth of focus of the camera. CD, New Zealand Geological Survey Collection, Lower Hutt. Scale = 1cm. B, Posterior part of the right ilium (CD 529) of a dryosaur-like ornithopod from the Maungataniwha Sandstone, Mangahouanga Stream. Scale = 1cm. C, Fragment of sauropod rib (CD 542) from the Maungataniwha Sandstone, Mangahouanga Stream. Scale = 5cm.

probably nodosaurian, dinosaurs — that have been identified from the Mangahouanga site (Molnar & Wiffen, 1994): the ankylosaurid bones found by the British Museum are as yet undescribed. Recent discoveries, which include a neoceratopsian, *Timimus hermani* and a possible oviraptorosaur (Rich & Rich, 1994; Currie et al., 1996) from Victoria, new ankylosaur material (Molnar, this volume) and a second skull of the large ornithopod *Muttaburrasaurus* (Molnar, this volume) from Queensland and a range of new Jurassic material from Antarctica (Hammer & Hickerson, 1994) suggest the early and widespread distribution of dinosaurs on the southern continent. So a greater understanding of the distributions of these polar dinosaurs, and their relationships to those from New Zealand, should result when more becomes known about these new discoveries.

The difficulties of close comparisons with New Zealand dinosaur bones are due to the paucity of fossil material collected and identified to date, hence the difficulty in finding homologous elements for comparison, as well as the discrepancy in geological age from most other Australasian /Antarctic sites.

FLORA AND FAUNA

The New Zealand marine fossil record is relatively good, and the Mangahouanga Stream site has contributed fossils to both marine (Crampton & Moore, 1990; Glaessner, 1980; Feldmann, 1993; Wiffen, 1981) and terrestrial records — including (possibly freshwater) turtles (Gaffney, pers. comm., 1989), flying reptiles (Fig. 4)(Wiffen & Molnar, 1988), a coleopteran (Craw & Watt, 1987) and a cockroach, which is still under study (Fig. 5).

A considerable quantity of fossil wood and plant material has been collected as well and this is currently being described by J.I. Raine. The available fossil plant material (wood, leaves, seeds and cone scales) is probably biased due to its preservation in shallow wave-base marine sediments — with only the tougher plant material surviving transportation by river to the region of deposition.

FIG. 2. The Mangahouanga Stream fossil site, showing a concretion eroding from the Maunataniwha Sandstone. Dinosaurian, and other, bones have been recovered from some of these concretions.

However eight types of angiosperm leaves and several seed capsules have been recognised and a considerable amount of podocarp-like foliage, similar to present-day material — though araucarian wood, leaves and cone scales dominate the collections (Raine, 1990; Crampton, 1990). It is hoped that ultimately the study of this material, combined with pollen and spore samples, will give a clearer indication of the botanical environment in which these dinosaurs survived.

POLAR DINOSAURS?

While it is evident that New Zealand's dinosaur population was subpolar in the geographic sense (Fig. 6) (Molnar & Wiffen 1994), it is not readily apparent that the climate and conditions in which they survived during the subsequent 15-20 million years were polar in the climatic sense. Water temperatures of 14.3°C are suggested from oxygen isotope studies by Stevens & Clayton (1971) and the marine record shows that plesiosaurs, mosasaurs and turtles were common in offshore waters in the Late Cretaceous. On land, there is evidence of continuous forest and plant growth — e.g., the Jurassic fossil forest at Curio Bay, Southland, the plant beds at Port Waikato, the lignite and plant fossils in both South and North Islands, material from Shag Point and Cretaceous material from Putarau, northwestern Nelson, Kaipara Harbour and Mangahouanga Stream (Bose, 1975; Edwards, 1926; Ettingshausen, 1891; Johnson, 1993; Kennedy, 1993; Mildenhall, 1970; Stevens, 1985) — which would have been essential to maintain a herbivorous dinosaur population, which in turn provided the food for the carnivorous dinosaurs.

However, palaeobotanical evidence appears to be accumulating to support the view of a cold Australasian polar climate, i.e., dominant angiosperms that were deciduous, dormant in periods of cold and darkness and dropping all their leaves over a short period to form leaf mats (Vickers-Rich & Rich, 1993; Johnson, 1993), though Pole (1993) suggests that this is still based on scant evidence. If true, presumably the deciduous plants would have, to some extent, replaced the conifers. From a practical point of view, such a deciduous vegetation would seem to have provided a meagre winter diet for the active, medium-sized dryosaur-like herbivorous dinosaur, while having the larger herbivores (sauropods) dependent on foraging for and browsing on fallen leaf mats to sustain life over prolonged periods of darkness and low temperature seems an unlikely scenario. How much nutriment could be derived from cold, semi-frozen, fallen leaves alone does not appear to have been calculated, but it was probably substantially lower than in still-attached leaves, because most nutrients are withdrawn from leaves before they are dropped. The feasibility of sauropods of even modest proportions 'grazing' on such a leaf mat is unclear, and even the question of how sauropods supported themselves in more temperate climates is unresolved (Ostrom, 1985). There is no evidence that herbivorous dinosaurs roamed New Zealand in large herds, as occurred in North America at this period, and the balance of both herbivores and carnivores would have been ultimately controlled on this island landmass by the quality, quantity, reproductive rate and availablity of the vegetation that formed the food supply. The deciduous vegetation does not appear to have been adequate to support the known dinosaurs through a cold polar winter.

Migration was not an option on this relatively small island landmass (Molnar & Wiffen, 1994). There is nothing in the dinosaur bones so far identified from the Mangahouanga Stream site to indicate dwarfism, as suggested for Victorian dinosaurs by Vickers-Rich & Rich (1993): a useful strategy if food resources or climatic conditions made hibernation necessary for survival. But hibernation for the relatively large dinosaurs (*Allosaurus*-size theropods and medium-size sauropods) found in New Zealand seems unlikely. Even remaining stationary for long periods in groups to conserve warmth would be unlikely for dinosaurs of this large size, while laying down

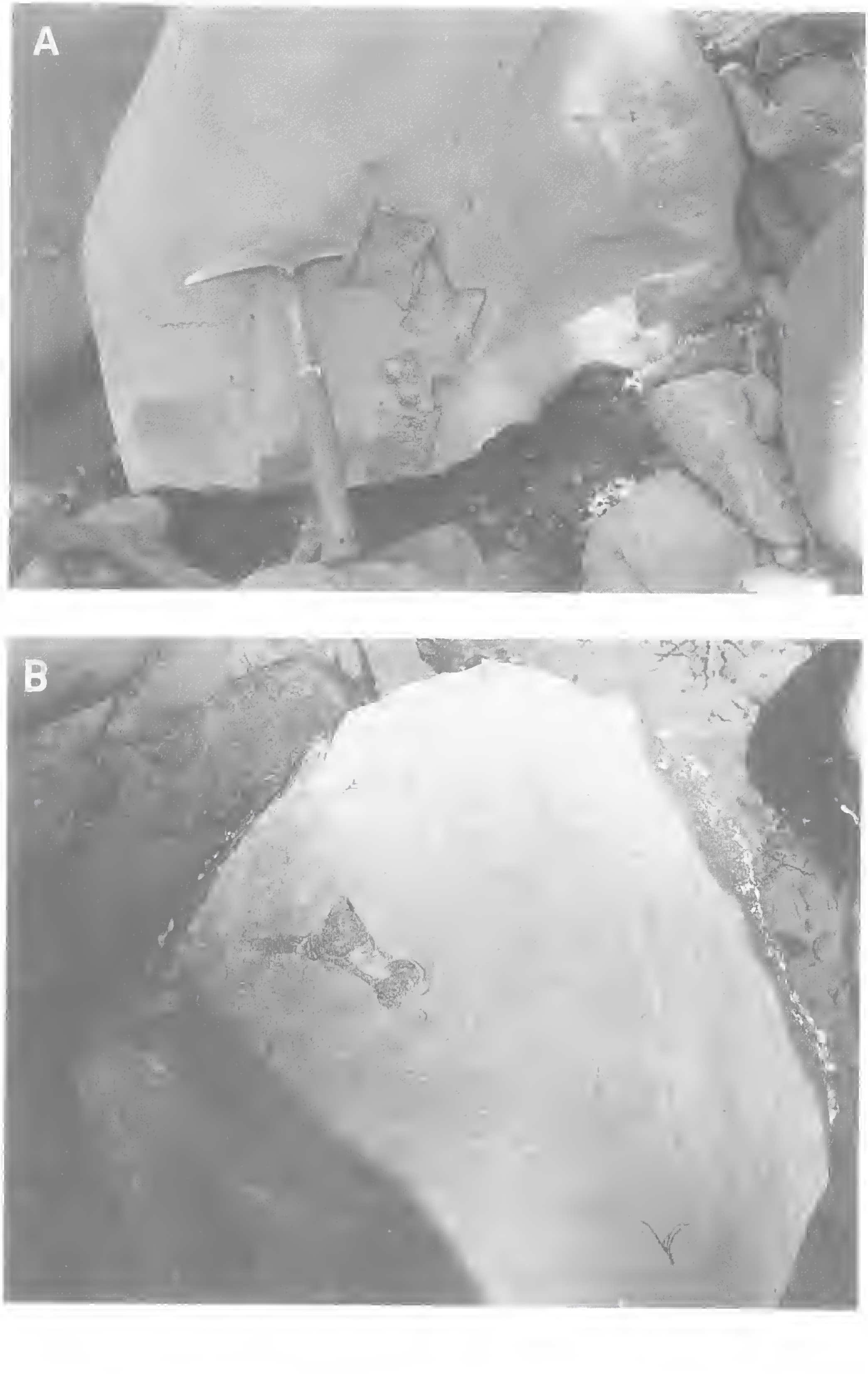
A
B

FIG. 4. Pterosaur distal ulna (CD 467) from the Maungatanwha Sandstone, Mangahouanga Stream. Scale = 1cm.

and curling up to keep the extremities warm would be improbable and finding sufficient handy caves to accommodate a number of animals of this size unbelievable. So there are no obvious behavioral strategies for the dinosaurs to have coped with a cold polar winter, either.

The difficulty of comparing the environment and dinosaurs from New Zealand and Australia arises from the difference in geological ages of these dinosaur faunas. The Australian dinosaurs range from Jurassic to Early Cretaceous, while Australia was still attached to Gondwana, whereas the only known bones from New Zealand are Late Cretaceous (Maastrichtian, 65-70 million years) when New Zealand had been adrift — and an isolated island — for approximately 15-20 million years after separation from Gondwana. It would appear that dinosaurs either adapted to whatever climatic changes they encountered over their 15-20 million years of occupation or the climate on the New Zealand landmass remained relatively stable and temperate. Doubtless even with a reasonably stable and temperate maritime climate, as probably existed, there were times when temperatures dropped or rose and conditions were unfavorable for dinosaurian life — with subsequent decreases in population size and reproduction at that time, such as occurs in the wild (and also with domesticated) animals today, but so far as is known of insufficient magnitude to wipe out any species before the end of the Cretaceous.

A living example of the resiliency that favours long-term survival is the Tuatara (*Sphenodon punctatus*): to quote Vickers-Rich & Rich (1993), '*this reptile can live in conditions down to 5°C, as long as it can sun itself*'. It must be remembered that *Sphenodon punctatus* was a New Zealand resident prior to and since the separation from Gondwana and that it apparently survived everything, including the Pleistocene ice ages from around 2 million to 14,000 years ago: an example of endurance over a long period of fluctuating temperature. Admittedly, the relatively small size and lower metabolic rate of the Tuatara allowed it to hibernate using holes and tunnels made by birds, or tree roots, for shelter. On the other hand the Moas, flightless ratite birds of large proportions whose ancestors are also believed to have lived on New Zealand since it separated from Gondwana, would have had difficulty in hibernating during the Ice Age, but survived until shortly after the arrival of man — around 1,000 years ago. This in spite of their higher metabolic rates and hence increased susceptibility to low temperatures and winter food shortages.

FIG. 5. Fossil cockroach, about 43mm long, from the Maungataniwha Sandstone, Mangahouanga Stream. The head was not found, but the right antenna (a) is present.

These are just two of a number of the forms which are known to have survived, regardless of climatic changes and turbulent geological events,

FIG. 3. A, Plesiosaurian vertebrae exposed in a concretion at the Mangahouanga Stream locality. B, Pedal phalanx of a large theropod exposed in a concretion at this locality. Both specimens show the characteristic structure of fossil bone as it is seen in the field and show how the bone can be easily recognised in situ.

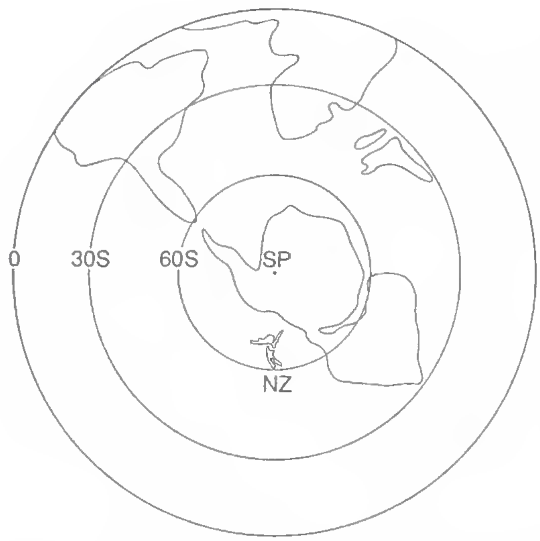

FIG. 6. Map of Late Cretaceous Southern Hemisphere in south polar projection showing the position of New Zealand (NZ). SP=South Pole.

since New Zealand's isolation 80-85 million years ago — though, as yet, there is little fossil evidence of their long period of residence. So it is not unexpected that the dinosaurs whether ectothermic or endothermic — considered by some to be the most successful forms of life on earth — were capable of surviving whatever changes occurred within their period of occupation of New Zealand. Especially as these changes seem to have been substantially less great than those undergone during the Caenozoic.

SUMMARY

Although the New Zealand contribution of dinosaur fossils is small at this stage, they do contribute to the overall knowledge of dinosaurs from the southern supercontinent, their dispersal and their survival until their worldwide extinction at the end of the Cretaceous. The fossils show that dinosaurs did inhabit New Zealand after it separated from Gondwana early in the Campanian. They arc the oldest evidence for terrestrial vertebrates in New Zealand, and arc the only near-polar dinosaurs from the Southern Hemisphere that lived on an island landmass.

The climate of New Zealand at that time seems to have been temperate, judging from the dinosaurian and plant fossils. Some plant material suggests that leaves were dropped during the winter forming leaf mats although conifers, not these deciduous forms, still appear to have dominated the forests in this region. The recovered dinosaur material shows no special adaptations to cold climates. However, the survival of Tuataras and Moas through the climatic variations that occurred in New Zealand since its separation from Gondwana shows that both endothermic and ectothermic forms were capable of surviving here for long periods. There is no reason to think that dinosaurs were not able to do so, too.

It is hoped that other New Zealand sites yielding Mesozoic terrestrial fossils will be found, and that more material will add to what we already know and expand our understanding of dinosaurian life and survival here on New Zealand and our place in the evolution of Gondwanan dinosaurs.

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